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On the long-term stability of altimetry satellites orbits

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Motivation

Starting with ERS-1 and TOPEX/Poseidon in 1992 the altimeter record spans already more than 25 years. Since orbits of altimeter satellites are a prerequisite for sea level studies and since any radial error directly maps in inconsistencies in the derived sea level, long-term stability of orbits of altimeter satellites is very important, especially for investigation of global mean and regional sea level changes. Therefore, we review processes and models that have an effect on the long-term stability of altimetry satellite orbits.

Summary

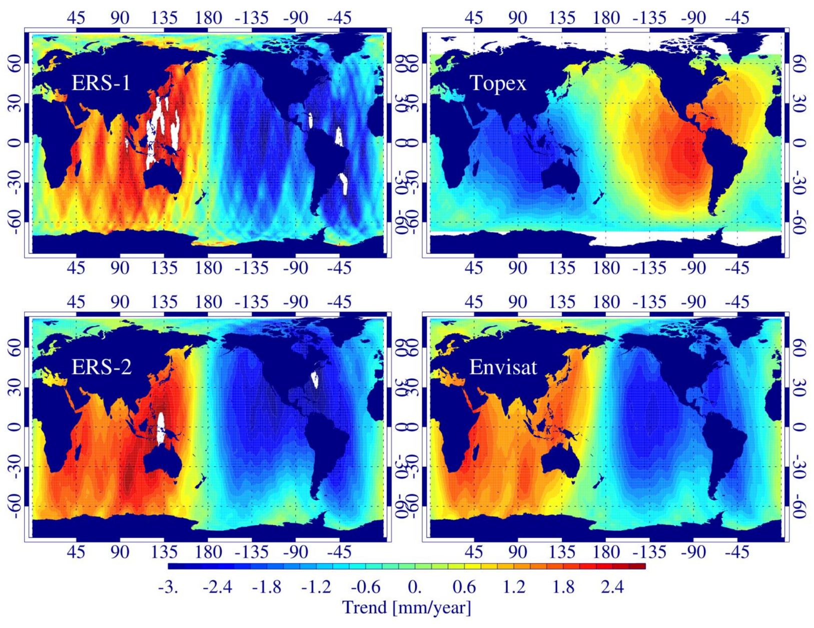
Even state-of-the-art time-variable Earth's gravity field models, like e.g. EIGEN-6S2 and EIGEN-6S4, show up to 0.4 mm/year differences in the regional sea level (SL) trend.

The replacement of ITRF2008 by ITRF2014 reference frame realization causes the differences in the regional SL trend up to 0.4 mm/year for TOPEX/Poseidon, 0.5 mm/year for Jason-1 at 2007-2012, and 1.0 mm/year for Jason-2 at 2008-2015.

Reference frame realizations DTRF2014 with non-tidal loading corrections and JTRF2014 provide the smallest RMS fits and smallest absolute mean fits of Satellite Laser Ranging (SLR) residuals for Jason-2 among the ITRS realizations tested. ITRF2014 shows notably larger mean fits of SLR observations than JTRF2014 and DTRF2014.

We stress the importance of taking into account non-tidal high-frequency Earth's atmospheric and oceanic mass changes and using of improved orbit modeling for altimetry satellites.

Influence of the Earth's time variable gravity field models on the regional sea level trend



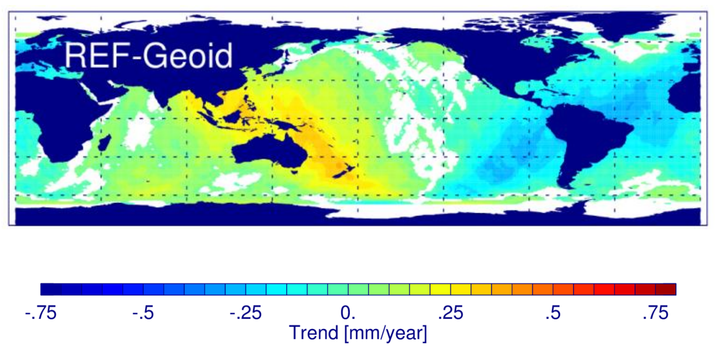


Fig. 1 (right): the replacement of EIGEN-6S4 by EIGEN-6S2 (both models have drift terms) for TOPEX shows regional sea level trend differences – up to 0.4 mm/year (Esselborn et al., 2018)

Fig. 1 (left): up to ±3 mm/year differences in the regional sea level trend due to the impact of the drift terms of the Earth's geopotential models: time-variable EIGEN-6S versus stationary EIGEN-GL04S (Rudenko et al., 2014).

Impact of non-tidal high-frequency Earth's atmospheric and oceanic mass variations

AOD product	ERS-1	ERS-2	Envisat	TOPEX/ Poseidon	Jason-1
No AOD	1.89	1.89	0.46	1.03	0.78
RL04	1.84	1.84	0.40	1.02	0.76
RL05	1.82	1.83	0.40	1.02	0.76

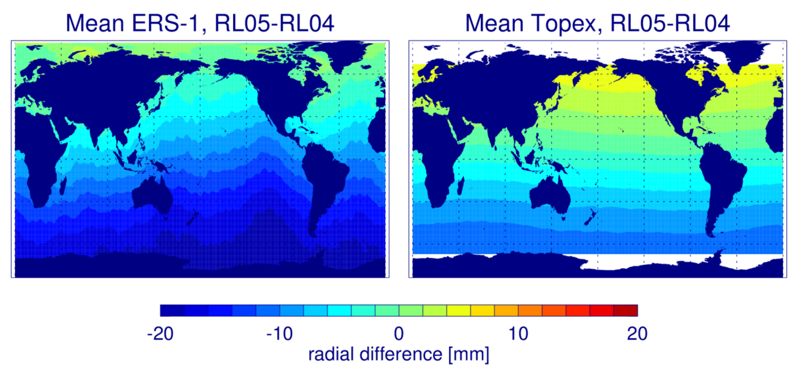


Table 1: using of Atmospheric and Oceanic De-aliasing Level-1B (AOD1B) RL04 product reduces 2-day radial arc overlaps (cm), as compared to the case, when no AOD product is used. The AOD1B RL05 product performs a bit better than RL04 for ERS-1 and ERS-2 (Rudenko et al., 2016).

Fig. 2: using AOD1B RL04 instead of AOD1B RL05 for orbit computation causes up to 1 cm mean radial orbit differences for ERS-1 and TOPEX in the polar regions (Rudenko et al., 2016).

Impact of improved orbit modeling on the RMS and mean values of crossover differences for TOPEX/Poseidon

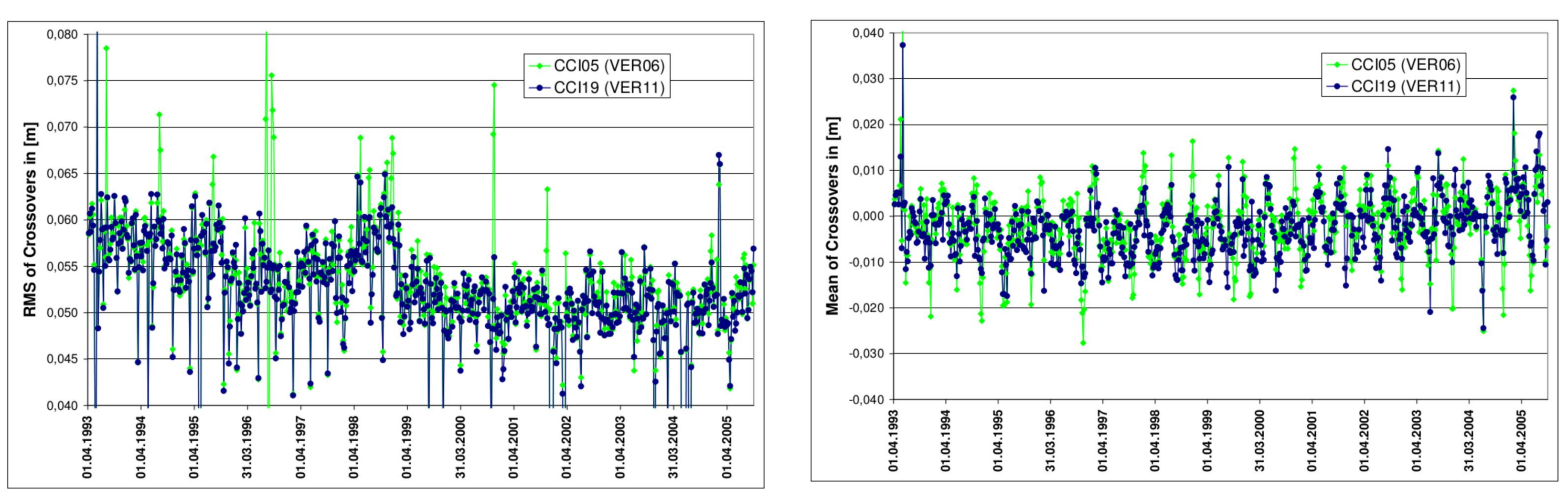


Fig. 3: improved orbit modeling, mainly of satellite macromodel, resulted in reduced scatter of RMS (left) and mean (right) of crossover differences computed using GFZ VER11 orbits as compared to those of GFZ VER05 orbits of TOPEX/Poseidon at the time span from April 9, 1993 until September 30, 2005 (Rudenko et al., 2017).

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Investigation of the orbit-related sea level errors for TOPEX at seasonal to decadal timescales

Regional maximum error	(SLR+ DORIS) – SLR	(SLR+ DORIS) – DORIS	ITRF2008 – ITRF2014 frames	EIGEN-6S4 – EIGEN-6S2 models	GFZ – GSFC orbits	GFZ – GRGS orbits
rms (mm)	7.2	9.3	2.4	3.5	7.4	10.7
Annual amplitude (mm)	1.4	2.1	0.4	3.2	5.4	5.6
rms 5-yr trend (mm/year)	0.5	0.6	0.2	0.4	1.2	0.9
Δ decadal trend (mm/year)	0.2	0.4	0.2	0.4	1.0	0.7

Table 2. Impact of the subset of observations (SLR and DORIS versus SLR-only and DORIS-only), ITRS realization (ITRF2008 versus ITRF2014), geopotential model (EIGEN-6S4 versus EIGEN-6S2), a choice of the orbit solution (GFZ versus GSFC and GFZ versus GRGS) on the regional radial errors for TOPEX (1993-2004, Esselborn et al., 2018).

Impact of various ITRS realizations on the RMS and mean fits of Satellite Laser Ranging observations of Jason-2

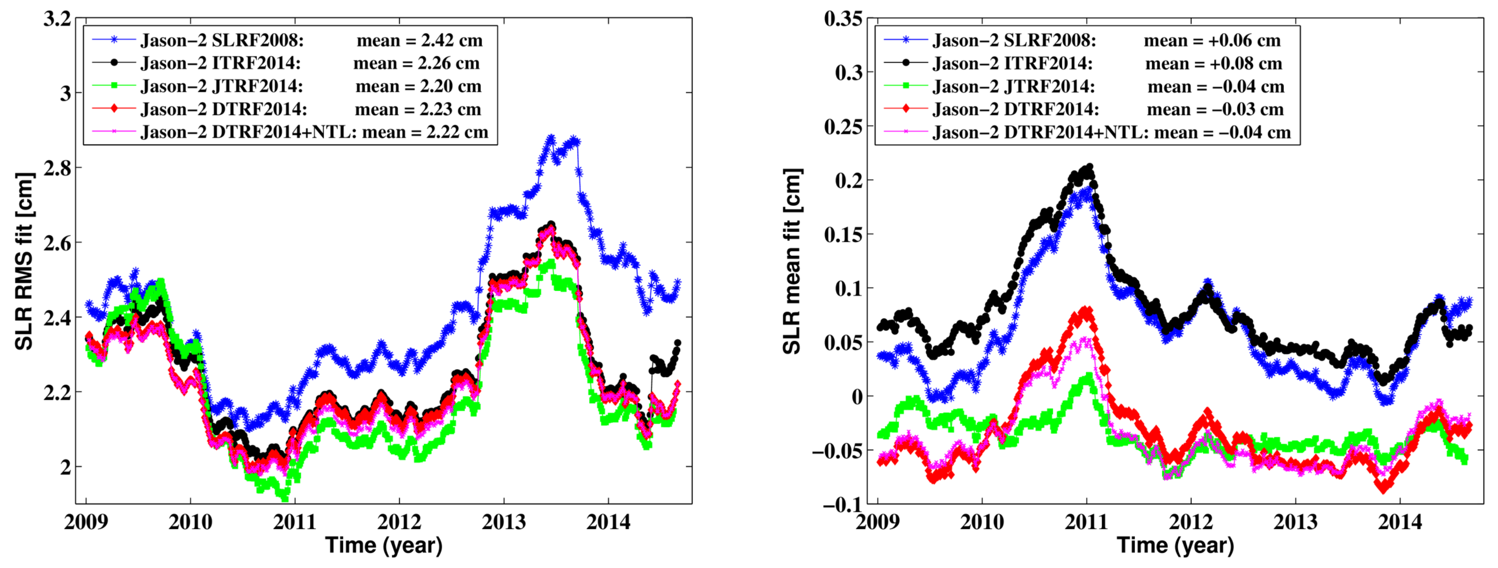
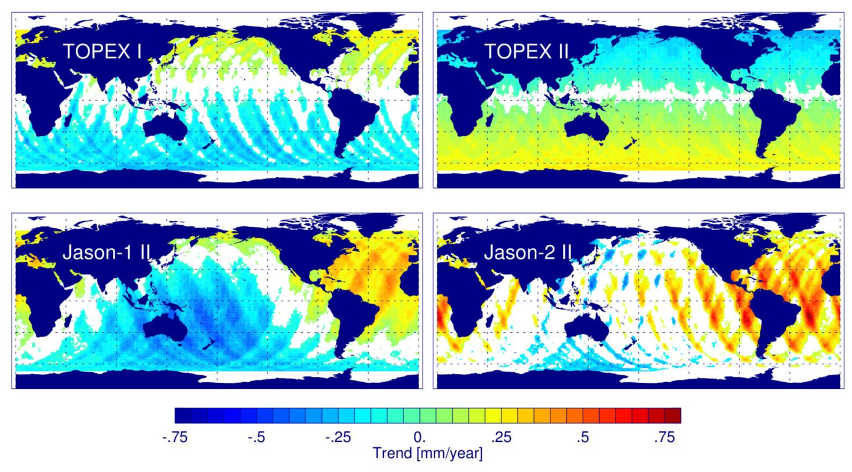


Fig. 4: Three new ITRS realizations were published in 2016. They are ITRF2014 derived at IGN, DTRF2014 computed at DGFI-TUM and JTRF2014 available from JPL. We study their performance, as compared to the previous realization for SLR stations – SLRF2008. DTRF2014 with non-tidal loading (NTL) corrections and JTRF2014 provide the smallest 50-week running averages of RMS fits and smallest absolute mean fits of SLR residuals for Jason-2 among the ITRS realizations tested for precise orbit determination. ITRF2014 and SLRF2008 show notably larger mean fits of SLR observations than JTRF2014 and DTRF2014 (Rudenko et al., 2018).

Impact of terrestrial reference frame realizations (ITRF2014 versus ITRF2008) on the regional sea level trend and internal orbit consistency



Reference frame	TOPEX/ Poseidon	Jason-1	Jason-2
ITRF2008	0.89	0.79	0.56
ITRF2014	0.83	0.77	0.53
Improvement	0.06 (6.6%)	0.02 (2.3%)	0.03 (5.9%)

Fig. 5: Radial trend differences computed using orbits derived in the ITRF2008 and ITRF2014 reference frames for the following satellites and periods: TOPEX I (Apr. 1993 - May 1997), TOPEX II (June 1997 - Sep. 2005), Jason-1 II (Oct. 2007 - Feb. 2012), and Jason-2 II (Mar. 2012 - Apr. 2015). Regions with formal errors larger than the fitted value are masked out (white, Rudenko et al., in review).

Table 3: Mean values of the 2-day radial arc overlaps (cm) and their improvement obtained for TOPEX/Poseidon (from 23.09.1992 to 09.10.2005), Jason-1 (from 13.01.2002 to 05.07.2013) and Jason-2 (from 05.07.2008 to 06.04.2015) orbits derived using ITRF2008 and ITRF2014 at the time spans given (Rudenko et al., in review).

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